AD-A104 371 WEBB ASSOCIATES YELLOW SPRINGS OH F/G 6/19
PHYSIOLOGICAL DESIGN GOALS FOR THERMAL PROTECTION OF DIVERS.(U)
SEP 80 P WEBB N00014-80-C-0193
UNCLASSIFIED NL

END
DATE FILMED
0 81
DTIC

Report of the Naval Medical Research & Development Command

PHYSIOLOGICAL DESIGN GOALS FOR

THERMAL PROTECTION OF DIVERS

Supersedes AD-A100991

PHYSIOLOGICAL DESIGN GOALS FOR THERMAL PROTECTION OF DIVERS

Prepared at a conference on
September 5, 1980
at
Bethesda, Maryland

Prepared by Webb Associates, Yellow Springs, Ohio,
under ONR contract N00014-80-C0193 with funds provided by the
Naval Medical Research and Development Command

Approved and Released by

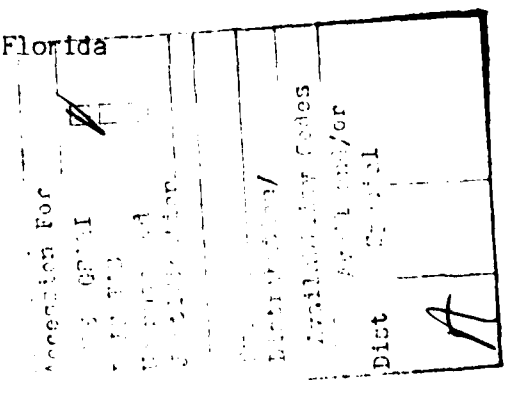
James F. Kelly
CAPT DC USN
Commanding Officer
Naval Medical Research and Development Command

Foreword

The predecessor of this document was a report entitled "PROPOSED THERMAL LIMITS FOR DIVERS: A Guide for Designers of Thermally Protective Equipment", which was written in July 1976 and circulated informally. During the past four years, there has been considerable progress in physiological research and an increased interest in diver thermal protection. Therefore, under the auspices of the Naval Medical Research and Development Command, a conference was arranged to consider revisions of the original document. A two-day workshop of the Undersea Medical Society on thermal physiology in diving and its effect on equipment design had served to update many of the conferees. The revision took place the following day, September 5th, 1980, in a meeting room of the Federated American Societies for Experimental Biology, Bethesda, Maryland (arranged by the Undersea Medical Society). Those in attendance were chosen to represent not only the scientists active in research but also the potential users of the revised document.

List of Attendees:

Walter Bergman
Office of Supervisor of Diving, Naval Sea System Command, Washington, D.C.
John Brady, LT, MSC, USN
Naval Medical Research Institute, Bethesda, Maryland
Frank Golden, Surg. Cdr., RN
Institute of Naval Medicine, Alverstoke, Hants., England
K.M. Greene, CDR, MC, USN
Naval Medical Research and Development Command, Bethesda, Maryland
M. Lew Nuchols
Naval Coastal Systems Center, Panama City, Florida
Raymond Sphar, CAPT, MC, USN
Bureau of Medicine and Surgery, Washington, D.C.
James Vorosmarti, CAPT, MC, USN
Naval Medical Research and Development Command, Bethesda, Maryland
Paul Webb, M.D.
Webb Associates, Yellow Springs, Ohio
John Zumrick, CDR, MC, USN
Navy Experimental Diving Unit, Panama City, Florida



PHYSIOLOGICAL DESIGN GOALS FOR THERMAL PROTECTION OF DIVERS

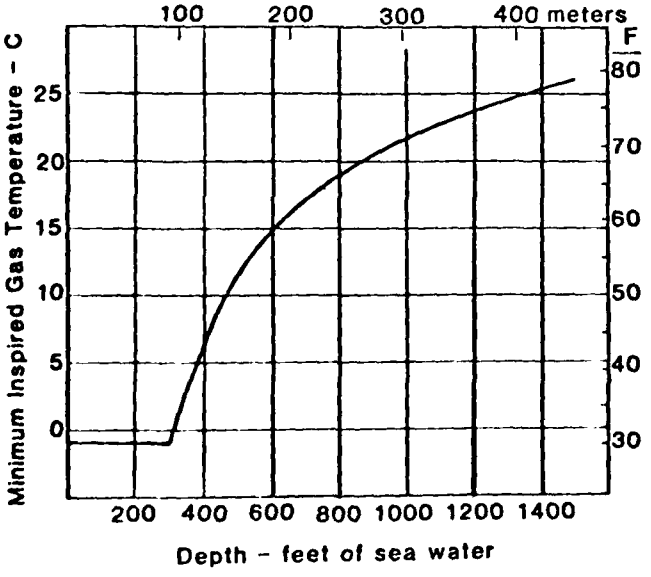
If producing a state of complete thermal comfort in all underwater situations is an unrealistic requirement for protective equipment, limits must be set on the amount of deviation from comfort that can be allowed. Based on present knowledge of physiological and performance effects of cold exposure, a diver or underwater swimmer should be able to perform his assigned tasks and be relatively safe if the following conditions are met. Newly designed equipment should be tested by methods generally accepted in thermal physiology. It is to be emphasized that the purpose of this guidance is to set goals for the design of equipment. It is not intended as an acceptance standard or military specification.

The following four conditions apply concurrently:

1. Maximum net body heat loss (change in enthalpy) of 3 kcal/kg of body weight.
2. Core temperature not lower than 36 C, or a decrease of 1 C, whichever is lower.
3. Mean skin temperature not lower than 25 C, and no individual skin temperature lower than 20 C, except that of the hand, which may go as low as 15 C.
4. Minimum inspired gas temperature as a function of depth as specified by the figure and table below.

When applying heat to a man, either as supplemental heating in cold water or during rewarming of a chilled diver, the following limits apply:

1. No individual skin temperature higher than 41 C.
2. Maximum inspired gas temperature of 45 C for up to one hour and 40 C for indefinitely long exposures.



DEPTH fsw	MINIMUM INSPIRED GAS TEMPERATURE C	F
300	-1.0	30.2
400	6.0	42.8
500	11.5	52.7
600	14.1	57.9
700	17.0	62.6
800	18.7	65.7
900	20.5	68.9
1000	21.9	71.4
1100	22.7	72.9
1200	23.7	74.7
1300	24.6	76.3
1400	25.3	77.5
1500	25.9	78.6

Discussion

Briefly, the design goals are based on the following considerations:

A net heat loss of 3 kcal per kilogram of body weight is tolerable if not incurred as rapidly as, for example, in the sudden immersion of nude men in cold water. A diver wearing inadequate thermal protection might lose this amount of body heat in 1 to 1.5 hours, feel quite cold and shiver strongly. He is warned by these symptoms and terminates the exposure voluntarily. However, 3 kcal/kg lost over three to eight hours causes rather mild core and surface temperature decreases, a mild sense of cold, and little shivering, but this may be the beginning of behavioral changes which could be potentially dangerous. Normalizing the heat loss by body weight is consistent with the observation that large people tolerate far more heat loss than small ones. While net heat loss (heat loss minus heat production) is not a feasible measurement except in special laboratories, it is nevertheless a useful datum for engineering calculations.

A core temperature of 36 C is a conservative low limit for design purposes. Divers whose deep temperatures are no lower than this are not in hypothermia. Medically speaking, hypothermia of significant degree is defined as a core temperature lower than 35 C. The added definition "or a decrease of 1 C, whichever is lower" is included because during the normal circadian rhythm of body temperature it is common for core temperature to fall to 36.5 C overnight. A diver who happens to begin a dive when his core temperature is below 37 C is safe if he loses only 1 C in core temperature-provided, of course, that the low starting temperature was not low as the result of an immediately preceding cold dive.

Skin temperature limits derive from many laboratory and field measurements during various kinds of cold air and water exposures. When the general skin surface is 25 C, there is a strong sensation of cold. Specific areas colder than 20 C are painfully cold, except for the fingers and hands which can usually stay painfree down to 15 C.

The minimum temperatures of breathing gas at depths below 300 fsw, shown in the figure, are based on new experiments from the Navy Experimental Diving Unit. They are temperatures which will produce a drop in core temperature of 1 C in 4 hours, when surface heat loss has been minimized. These gas temperatures are far higher than those previously recommended (the Braithwaite curve), and may thus be conservative. They should nevertheless be achievable with respiratory gas heaters.

When designing equipment to heat a diver, the goal is to warm the skin, but not to the point of pain or damage. 41 C is a conservative upper limit. Similarly, when heat is applied via the respired gas, a temperature of 45 C for up to an hour (at any vapor pressure up to saturation at sea level pressure) avoids discomfort and damage to the lining of the respiratory tract. A lower limit of 40 C for longer times is chosen to prevent damage to the cilia of the respiratory tract.

The design goals represent compromises between medical conservatism and freedom for the designer. These goals should be revised as new evidence accumulates.

INITIAL DISTRIBUTION:

CNO (OP-23)
NAVSEA (OOC, 05R2)
ONR (441)
BUMED (3C2)
NAVXDIVINGU
NAVMEDRSCHINST
NAVSUBMEDRSCHLAB
NAVDIVESALVTRACEN
NAVCOASTSYSCEN
NAVCLOTEXTRSCHF
ONRBRO LONDON (502)
IEP B-12 (U.K.)
IEP C-21 (Canada)
MWDDEA Australia
MWDDEA France
Webb Associates
Undersea Medical Society
Dr. Charles Johnson, Duke Univ.
Dr. Eugene Wissler, Univ. of Texas

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-[redacted]	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* PHYSIOLOGICAL DESIGN GOALS FOR THERMAL PROTECTION OF DIVERS		5. TYPE OF REPORT & PERIOD COVERED Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) PAUL WEBB		8. CONTRACT OR GRANT NUMBER(s) N00014-80-C-0193
9. PERFORMING ORGANIZATION NAME AND ADDRESS WEBB ASSOCIATES YELLOW SPRINGS, OHIO 45387		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 63713NM0099-PN.002
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Medical Research & Development Command, National Naval Medical Center, Besthesda, MD 20014		12. REPORT DATE September 1980
		13. NUMBER OF PAGES 8
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED
		15a. DECLASSIFICATION/ DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Prepared at a conference on September 5, 1980 at Bethesda, Maryland

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Thermal Physiology, Diving, Hyperbaric Medicine, Hyperbaric Conditions, Diving Equipment Design, Workshops, Tolerance (physiology), Hypothermia, Exposure (physiology), Protective Clothing, Body Heat Loss, Underwater Clothing

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The predecessor of this document was a report entitled "PROPOSED THERMAL LIMITS FOR DIVERS: A Guide for Designers of Thermally Protective Equipment", which was written in July 1976 and circulated informally. Since that date there has been considerable progress in physiological research and increased interest in diver thermal protection. Therefore, under the auspices of the Naval Medical Research and Development Command, a conference was arranged to consider revisions of the original document.

The purpose of the guidance provided is to set goals for the design of

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

equipment. It is not intended as an acceptance standard or military specification. The design goals represent compromises between medical conservatism and freedom for the designer. They should be revised as new evidence becomes available.